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Ecologies of participation in socio-technical change: The case of energy system transitions

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ABSTRACT

Studies of societal engagement with socio-technical change are undergoing a systemic turn. Rather than simply viewing public engagement in science, policy and behavioural change in terms of discrete cases, key social theories in deliberative democracy, practice theory, socio-technical transitions and co-productionist scholarship in science and technology studies (STS) are moving to consider how diverse forms of participation interrelate in wider systems. In this paper we take stock of these advances to develop a conceptual framework for understanding ecologies of participation in socio-technical and democratic systems, grounded in relational co-productionist theory in STS. The framework is illustrated through empirical analysis of a systematic mapping of participation in UK energy system transitions between 2010 and 2015. This provides the first insights into system-wide patternings, diversities and inequalities of energy participation, the significant types of interrelation between practices of public engagement within wider ecologies of participation, and their mutual construction with political cultures and constitutions. The value and implications of adopting an ecologies of participation approach are considered with respect to the theoretical, empirical and practical challenges of understanding and building more inclusive, responsible and just socio-technical (energy) transitions.

1. Introduction

In this paper we develop a new perspective on 'participation' in socio-technical change with specific reference to energy system transitions. Notions of participation, inclusion and societal engagement have become central to realising socio-technical transitions that are more democratic [1], sustainable [2], socially shaped [3], responsible [4], just [5], and responsive to public values and human needs [6]. In addressing energy issues vis-à-vis climate change public engagement is variously viewed as crucial to communicating the problem [7], establishing public acceptability of policy and technological interventions [8], prompting behavioural change [9], mobilising grassroots citizen action [10], through to addressing aspirations for democratic steering and public accountability [11]. What publics think, know, say and do have become core concerns of energy research, policy and practice.

Even though there has been undoubted progress, our starting point is the contention that existing approaches to participation in socio-technical change have failed to address increasing complexities of public relations with energy systems and recent developments in social and political theory. Mainstream approaches to societal engagement with energy (or any other domain) most often adopt fixed, pre-given meanings of what it means to participate, and imagine involvement occurring in discrete events or cases in particular parts of wider socio-technical systems [12]. While energy research has developed 'whole system' approaches for technically modelling energy transitions (e.g. [13]), on questions of societal and democratic engagement social science and policy-practice remains compartmentalised in theory, modes of empirical study and models of engagement. For example, behaviour change studies tend to centre on the workplace, the home and efforts to reduce energy demand (e.g. [14,15]); public opinion research and deliberative democracy approaches focus on sites of invited public deliberation and questions of 'social acceptability' that most often feed in to government and industry decision-making (e.g. [16,17]); whereas social movement studies and transitions management approaches respectively hone in on sites of protest or activism and sites of social innovation (e.g. [18]).

Just as interest in the human and social dimensions of energy systems is being mainstreamed [19], this fragmentation is undermining the potential contribution of the social sciences. There is growing unease over the ability of existing approaches to account for the increasingly complex, diverse and interconnected roles of publics in energy systems on the cusp of a post-carbon era [20,21,12,22], linked to

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trends in globalisation, market liberalisation, distributed energy production, the digital revolution and the rise of the internet.

The impetus for radically rethinking existing approaches to energy participation also comes from two important developments in the social sciences (much of which lies outside of the energy field). First, relational and materially sensitive theories are challenging mainstream 'residual realist' understandings of 'the public', participation and public issues as pre-given and external, to rather conceive of them as being constructed through the performance of socio-material practices and social science methods [23–26]. Second, is a 'systemic turn' in social and democratic theory relevant to societal engagement with socio-technical systems. This includes recent developments in practice theory [27], deliberative democratic theory [28], and science, and technology studies (STS) [29], which are moving from a case or event-based imaginary of participation to conceive of how multiple practices of participation interrelate as part of wider systems and constitutions.

In what follows, we build on these developments to set out a systemic approach to participation in socio-technical change. We move beyond mainstream approaches that view energy participation as something particular, pre-given and discrete to introduce the notion of 'ecologies of participation' as a means to understand the dynamics of diverse interrelating collectives and spaces of participation and their interactions with wider systems and political cultures. In Section 2 we provide an overview of mainstream approaches to energy participation in comparison to emerging relational and systemic approaches. This provides the basis to present a new conceptual framework for understanding systems and ecologies of participation in Section 3, which is grounded in relational co-productionist theories in STS. In Section 4 we apply this framework to the case of energy transitions, drawing on empirical material from a systematic mapping of participation in UK energy system transitions. Here we present new insights into system-wide patternings, diversities and inequalities of public engagement with energy, how practices of engagement interrelate and interconnect within wider ecologies of participation, and their mutual construction with political cultures and constitutions.

In the final discussion and conclusions we consider the value and implications of adopting an ecologies of participation approach with respect to the theoretical, empirical and practical challenges of understanding and building more inclusive, responsible and just socio-technical transitions in energy. While the focus of this paper is on developing and illustrating a new conceptual framework, we suggest that its systemic and ecological perspective on the diversities, emergence and stabilities of energy participation can enhance energy research and policy understandings of: the dynamics of socio-technical system change; ambiguities and contestations over the framing of energy system transitions; and systemic inequalities of inclusion and exclusion. It also has potential to cultivate more robust forms of social intelligence for energy governance that can be more responsive and accountable to continually emerging societal values, knowings and doings.

2. Beyond 'residual realism': energy participation as relational and systemic

In this section we identify three broad ways in which societal engagement with energy and low-carbon transitions is and can be conceived, considering literature from energy research and across the social sciences. In doing this we contrast mainstream approaches to energy participation with emerging relational and systemic perspectives. An overview of the key features and differences between these three perspectives, in relation to their underlying assumptions about publics and participation, is provided in Table 1.

2.1. Mainstream 'residual realist' perspectives on energy participation

The first perspective is closely associated with mainstream approaches to energy participation, most of which are well-established in energy research, policy and practice. This includes commonly adopted approaches for engaging societal actors with energy, such as behaviour change techniques (often grounded in the fields of social psychology (e.g. [14]) and behavioural economics (e.g. [9,15]), public attitude surveys (e.g. [17]), deliberative processes (e.g. [16]), transitions management (e.g. [3]), and sometimes forms of engagement enacted in social movements (e.g. [18]). While the intentions of these engagement approaches diverge considerably – ranging from encouraging the public to adopt more sustainable energy behaviours through to eliciting opinions about energy policy and facilitating wider public debate – they are most often imbued with and *perform* a particular conception of participation and the public. This includes the dominant assumptions of (see also Table 1):

- publics engaging with socio-technical change as individuals or groups of individuals;
- participation in socio-technical change as occurring in discrete events and processes, which can be grown and 'scaled up';
- participation as being fixed or pre-given in terms of the *model* or format of engagement (e.g. deliberative citizens jury, behaviour change initiative, activist group), the *subjects* of engagement (e.g.representative publics, consumers, affected stakeholders) and the *objects* of engagement (e.g. the energy-related issue or technology); and
- participation as able to be technically improved or perfected through objective evaluation against 'best practice' criteria (like inclusion, representativeness, attitudinal change, impact on decision-making).

Following Chilvers and Kearnes [26], we term this a 'residual realist' perspective on participation and the public. This is because while many of the aforementioned mainstream approaches to energy participation are prompted by constructivist views on socio-technical change, 'the public', 'participation' and 'democracy' remain as naturally occurring, pre-given categories that can be evaluated against externally prescribed (normative) principles. The emphasis is on *doing* energy participation through refining techniques to more accurately and completely represent or mobilise energy publics in achieving desired socio-technical change.

2.2. Relational perspectives on 'energy' participation

The second perspective identified in our review has become firmly established across the interpretive social sciences over the past decade and has in some instances begun to cross over into the worlds of policy and engagement practice. It is a relational perspective underpinned by approaches which see participation in socio-technical change as always occurring through the performance of heterogeneous collective practices. Some of these approaches are mainly analytical, focusing on understanding the dynamics of (energy) participation. These include science and technology studies (STS) approaches to participation – growing out of developments in actor network theory, including object-oriented approaches [25], technologies of participation [30], and ethno-epistemic assemblages [31] – which have taken practices of public involvement in issues as their focus, each offering different explanations over what brings participatory collectives into being [12]. Social practice theory (SPT) offers another relational approach which has become quite well established in energy research, focusing for the most part on everyday social practices which use energy [32]. Some relational approaches are more interventionist in emphasis, bringing forward new ways of doing energy participation in more deliberately experimental and reflexive ways, including collective experimentation [1,33], speculative design [34], and Deliberative Mapping [35].

Relational practice-oriented approaches assume that even a single person never participates alone, but always through collective practices comprising networked relations with material elements, infrastructures,

Table 1
Key features of residual realist, relational and systemic conceptions of participation in socio-technical change.

	Residual realist	Relational	Systemic
Publics are/act through	Autonomous individuals	Socio-material collective practices	Multiple interrelating collectivities
Participation is	Pre-defined, discrete processes	Co-produced, experimental	Diverse, systemic
The object of participation is	Specific, pre-given	Open, emergent, overflowing	Multiple, entangled
Relation between participation & change	Linear, cause-effect	Non-linear, emergent	The outcome of multiple swarming vitalities
The problem of participation is one of	Extension	Relevance	Reflexive steering
'Good' participation is	Inclusive, representative, impactful	Reflexive, anticipatory	Responsive, responsible

technologies, knowledges, meanings, other people, policy instruments and so on (see Table 1). Under this view key dimensions of energy participation, including public identities and the form of participation itself, are constructed through the performance of participatory practices rather than being simply assumed and pre-given [12]. Furthermore, practices of participation with energy never occur in isolation. They are always co-produced – i.e. entangled with, shaped by, and shaping other collective practices and the energy systems in which they are situated. Relational approaches provide the resources to open up to the diversities, complexities and multiple productions of participatory practices across energy systems. However, they tend to focus on discrete collectives or instances of participation rather than offering a broader systemic perspective.

2.3. Systemic perspectives on 'energy' participation

A third perspective views participation and publics from a more systemic standpoint. This is a view that is only just emerging in academic social science, and has not yet been applied to energy policy and related engagement practice. Systemic perspectives move beyond a narrow imagination of participation as discrete 'events' to understand how multiple practices of engagement interact in wider systems. The move to a 'systems of participation' approach is reflective of how the state of the art in the theory and practice of participation has rapidly advanced in the last few years. For example, leading edge work on how to bring about effective public deliberation on crucial issues like collective energy futures has shifted from trying to perfect discrete engagement processes that can claim to be representative and inclusive of 'the public', to approaches more interested in building an effective 'deliberative system' where multiple forms of public involvement interconnect and can flourish [28].

Socio-technical transitions approaches [3] have for some time adopted a systemic perspective on socio-technical system change but lacked resolution around actor dynamics and the politics of transitions [36]. More recent work has begun to address the participatory democratic aspects of socio-technical systems [37,38]. In addition, recent work in SPT has sought to move beyond a focus on situated practices performed in mostly domestic settings to focus instead on the relationships between practices as they extend through space and time to make up particular systems (such as an energy system). Here, work has begun to explore the nature and density of connections between different practices. Shove et al. [39], for example, distinguish between co-located but loosely connected 'bundles' of practice and more densely integrated 'complexes' of practice, whilst Watson [27] notes that practices are interconnected, and therefore influence one another, through shared elements, shared 'carriers' or performers, and through their arrangement and sequencing across space and time.

Finally, work in the co-productionist tradition in STS helps articulate two systemic understandings of participation. The first approach is object-oriented and pragmatist. It focuses on the objects which give rise to, mediate, or are produced through public involvement with energy – for example material technologies like smart homes or oil pipelines and their energy-related issues [40,25]. Such insights emphasise the multiple forms of public involvement that intermingle in energy-related issue spaces or controversies. The second systemic STS approach focuses more on institutional dimensions and human agency, with an interest in how collectively acceptable forms of public reason solidify and change over time in particular settings [41]. These approaches have tended to focus on a particular nation-state, or compare between nation-states, developing an in-depth analysis based on the specificities of national culture and history. Such insights argue that understanding systems of energy participation depends on exploring how they are powerfully shaped by and shape the political cultures and constitutions in which they are situated [29]. Despite some differences, then, systemic approaches emphasise how multiple diverse collectives of participation interrelate in wider systems as multiple swarming vitalities (cf. [42]) shaping socio-technical stabilities and change.

3. A framework for understanding ecologies of participation

Through incorporating selected aspects of the relational and systemic perspectives reviewed above, in this section we introduce a relational and co-productionist framework for understanding and intervening in systems of energy participation. The framework, as presented in Fig. 1, is based on the approaches previously developed by Chilvers and Kearnes [43] and Chilvers and Longhurst [12], grounded in co-productionist thinking in STS. It conceptualises three relational spaces of participation that interrelate to form a system of participation in socio-technical change.

First, the triangles at the centre of the diagram represent **collective participatory practices** through which publics engage in socio-technical change and the energy system. This forms a basis for understanding the emergence of all forms of participation as heterogeneous socio-material collectives comprising the mutual interweaving of social, normative, cognitive and material elements. Rather than pre-existing a priori, the *subjects* (including participating publics), *objects* (issues or material devices) and *models* (political ontologies or formats) of participation are actively *co-produced* through the performance of collective participatory practices (see [12]) – which are shaped by (and in turn shape) extant orders on these dimensions.

These three dimensions (i.e. subjects (S), objects (O) and models of participation (P)) are co-produced through the assembling of particular material settings, knowledges, devices, meanings, and configurations of human and non-human actors that make up collective participatory practices (cf. [31,1,26,44]). The multiple triangles at the centre of Fig. 1 signify the diversity of different collective practices through which people participate in and relate to energy systems. Instead of predefining the who, what and how of participation, analytically our approach opens up to the sheer diversity of participatory practices through which publics engage in energy transitions (cf. [45]) including and going beyond: public opinion surveys, deliberative process, behaviour change initiatives, digital democracy, citizen science, protests,

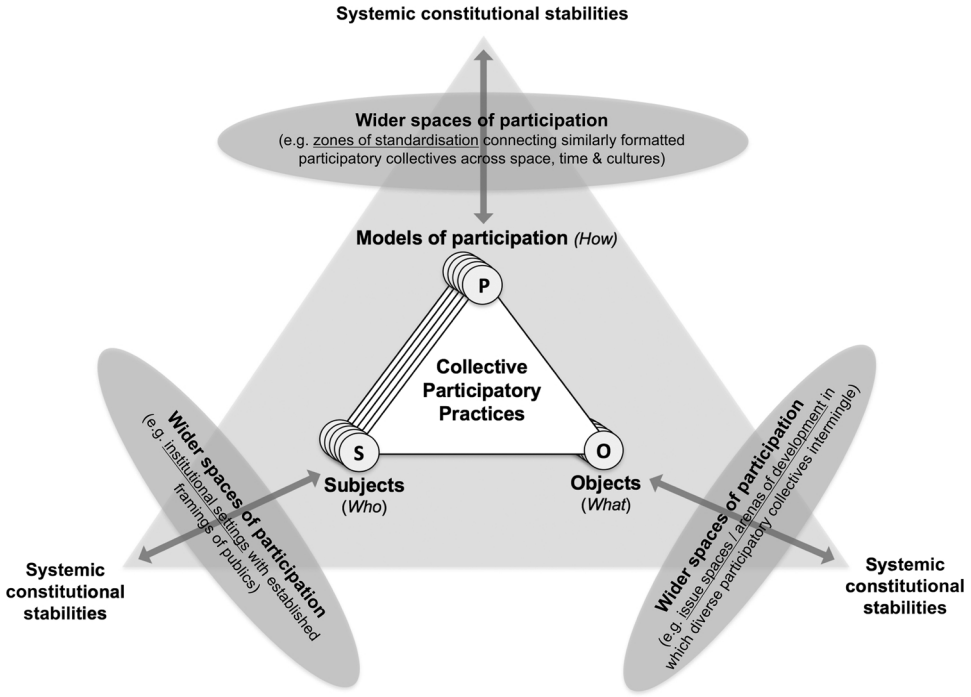

Fig. 1. A relational co-productionist framework for understanding ecologies of participation in socio-technical systems.

activism, community energy, and everyday social practices which consume energy. This leads us to form a more open definition of public participation as: heterogeneous collective practices through which publics engage in addressing collective public issues (in this case 'energy-related' issues), whether deliberately or tacitly, which actively produce meanings, knowings, doings and/or forms of social organisation.

While this highlights potential diversity and emergence of public engagements with energy, collective participatory practices form part of two further types of relational space depicted towards the outside of Fig. 1. The first is **wider spaces of participation** – i.e. spaces within which multiple participatory practices connect and interrelate. Wider spaces of participation can exist and form on any of the three dimensions of participatory practice: models, objects or subjects (see Fig. 1). For example, in relation to models of participation, zones of standardisation can form around a particular method, expertise or technology of participation (e.g. opinion polls or citizens' juries) which connect similar participatory collectives across space, time and cultures, often internationally (see [46,30,47]). Regarding the objects of participation, wider spaces of participation can also be spaces of difference where multiple participatory collectives cohere within a controversy or issue space [48,25] (e.g. around fracking, biofuels or fuel poverty), or otherwise an arena of development where they compete in shaping innovation pathways (e.g. the development of smart energy technologies) [49]. In terms of the subjects of participation, multiple participatory collectives can be connected with a wider space of participation, such as institutional settings, which prescribe and reproduce particular identities and imaginaries of publics (e.g. consumer-citizens, innocent citizens) [50]. As shown in Fig. 1, these wider spaces of participation thus form over space and time and serve to shape participatory practices in situ, but are in turn formed and shaped by them in a recursive relationship.

These wider spaces of participation are themselves *situated* within and extend beyond the energy system, which is represented by the grey triangle and the text on the outside of Fig. 1. Drawing on co-productionist work in STS, this aspect of our framework introduces the notion of the energy system-as-constitution (cf. [29,51]). This emphasises the importance of the national political culture and constitutional relations between citizens, science and the state within which an energy system is situated, in shaping (and being shaped by) the forms of participation that occur within it. The energy constitution exerts powerful **systemic constitutional stabilities** that are tied up in energy policies, laws, regulations, infrastructures, established social practices, socio-technical imaginaries, and collective forms of public reason that have become established within situated (national) political cultures over historical time. Energy constitutions are also subject to moments of transformative change, for example at times of crisis, following surprise events or as a result of changes in the energy policy landscape. It is the situated political culture of the energy constitution within which certain participatory ways of knowing and doing become seen as authoritative and are endowed with legitimacy and meaning (cf. [52]), while others become endangered. Under these constitutional conditions, then, certain forms of energy-related participation become more established, legitimate or prevalent than others.

So, in contrast to a vision of energy-related participation as the engagement of individuals in discrete engagement processes, our framework opens up to the existence of diverse, emergent and interrelating participatory practices, that form part of and interact with wider spaces of participation set within an energy system as constitution. Our framework therefore advances to focus on understanding **ecologies of participation** – i.e. the relational dynamics of diverse interrelating collective practices and spaces of participation which intermingle and are co-produced with(in) wider systems and political cultures. In this sense: "An ecological conception of participation suggests that is not possible to properly understand any one collective of participation without understanding its relational interdependence with other collective participatory practices, technologies of participation, spaces of negotiation and the cultural political settings in which they become established" ([43]: 52).

In introducing this ecological metaphor it is important to clarify that the ontology of our approach differs from popular realist meanings of ecology developed within the natural sciences (e.g. [53]), which understand natural (non-human) systems as being separate from society. Our approach is also distinct from the inherent realism of evolutionary economics that forms part of co-evolutionary approaches to understanding socio-technical system transitions such as the Multi-Level

Table 2
A summary of the 30 cases subject to further in-depth analysis as part of the systematic mapping.

In-depth case of energy participation	Key source
Case 1: UKERC Transforming the UK Energy System national citizen engagement process	Parkhill et al. [58]
Case 2: Reclaim the power activist group	Reclaim the Power [59]
Case 3: DECC's Low Carbon Communities Challenge	DECC [60]
Case 4: BBSRC's Bioenergy Distributed Dialogue	BBSRC [61]
Case 5: UK Government public engagement with shale gas and oil	TNS BMRB [62]
Case 6: DECC's My2050 simulator and public dialogue	Comber and Sheikh [63]
Case 7: Wind farm protests in Nant Y Moch, Wales	Mason and Milbourne [64]
Case 8: Northern Ireland's first community energy collective	NICE [65]
Case 9: Tilting at windmills dance installation	Allen and Jones [66]
Case 10: Customer Led Network Revolution academic project	Bulkeley et al. [67]
Case 11: DECC's public attitudes tracking	DECC [17]
Case 12: Energy Babble academic project	Febubabble [68]
Case 13: RENERGY Living Labs academic project	Dvarioniene et al. [69]
Case 14: Experiences of fuel poverty academic study	Middlemiss and Gillard [70]
Case 15: Energy Biographies	Henwood et al. [71]
Case 16: Domestic laundry practices academic study	Higginson et al. [72]
Case 17: Understanding Homeowners' Renovation Decisions	Wilson et al. [73]
Case 18: The Brighton Energy Co-op	Hielscher [74]
Case 19: iconnect academic study into commuting behaviours	Brand et al. [75]
Case 20: Drawing energy project at the Victoria & Albert Museum	Bowden et al. [76]
Case 21: Demand Energy Equality group	Demand Energy Equality [77]
Case 22: Reporting of fracking in the UK press academic study	Jaspal and Nerlich [78]
Case 23: Thermal comfort behaviours in UK office buildings academic field study	Liu et al. [79]
Case 24: Sentiment analysis of perceptions of the Big Six energy companies by Talkwalker	Beckman [80]
Case 25: Back Balcombe campaign	10:10 [81]
Case 26: UK residents' responses to high voltage power lines academic study	Devine-Wright and Batel [82]
Case 27: Smart Meters, Smart People field study in Northern Ireland	Liddell [83]
Case 28: Imaginations of low carbon rural futures in English villages academic study	Phillips and Dickie [84]
Case 29: Community food waste energy production projects in Sheffield and Devon academic study	Alexander and Reno [85]
Case 30: Londoners on Bikes	Aldred [86]

Perspective (MLP) (e.g. [54]). While attending to the complexities of social as well as technical change, in such approaches the evolutionary metaphor has most often been applied to understand how particular discrete technological objects and innovations have evolved over historical time. Furthermore, our relational ecologies approach is distinct from works on public engagement methods and discrete cases or events of participation that have invoked ecological metaphors (e.g. Gehrke [113]), including Heath and vom Lehn [55] who use the term ecologies of participation to describe multiple interactions by individuals around a discrete engagement process in the case of interactive exhibits in science museums.

Our approach develops a *constructivist relational ecology* that is much closer to STS understandings of the inherent ecology of interconnections between all socio-material collective practices that co-constitute natural and social worlds (cf. [56,57]). In our framework an ecology of participation is the interrelating assemblage of socio-material collectives of participation that make up and overflow the *situated* system-as-constitution of which they form part. Our approach thus moves away from bounded and reductionist approaches for understanding socio-technical and democratic systems. It allows for the inherent contingency, contestation and ambiguity of the *object* of socio-technical change through attending to the ways in which ecologies of participation always 'overflow' [1] – and thus continually animate the *meanings* of – the system-as-constitution (in this paper the UK energy system). Furthermore, the socio-material ecology in our framework is not an entirely flat ontology, but rather explains how powers of participation become lodged in both wider spaces of participation and the system-as-constitution (see Fig. 1) over historical time. Closely attending to existing and emerging power relations in this way can explain how some participatory collectives become dominant and recognised whereas others become endangered and de-publicised within wider socio-material ecologies.

4. Ecologies of participation in UK energy transitions

We now illustrate and apply the conceptual framework developed in this paper in a thematic analysis of empirical material from a systematic mapping of public engagement in UK energy system transitions between 2010 and 2015. The mapping method, which is explained in more detail in Pallett et al. [114] (see also Chilvers et al. [115]), was informed by the systematic review methodology developed by the UK Energy Research Centre (UKERC). This first involved establishing the scope and search terms of the review. In order to attend to diversities of energy participation a reflexive and agnostic approach was taken where a high number of synonyms were developed to account for diverse framings of the three dimensions of collective participatory practices established in Fig. 1 – i.e. (P) *the model of 'participation'* (49 synonyms in total including 'participation', 'involvement', 'engagement', 'social movement*', 'grassroots'); (S) *participating 'subjects'* (19 synonyms in total including 'public', 'citizen', 'consumer', practitioner*, societ*, activist*) and (O) *energy-related 'objects'* (58 synonyms in total including 'energy', 'electricity', renewable*, 'smart', 'demand reduction'). Synonyms were developed from an initial review of the literature and feedback from an expert panel. Searches were conducted through academic and non-academic search engines (Web of Knowledge, Scopus, Google Scholar and Google) which produced a large number of results that were screened to identify cases which contained sufficient material for analysis and comprised some form of collective practice through which publics and/or civil society engaged with energy transitions in the UK between 2010 and 2015. This time frame was sufficiently long to trace connections between participatory collectives and coincided with energy policy and constitutional developments during the term of the Conservative-Liberal Democrat Coalition Government.

The search and screening stages of the mapping produced a final corpus of 258 cases.[1] The corpus was then subject to qualitative coding analysis in relation to the framework presented in Fig. 1 to interpret

[1] Details of all 258 cases can be viewed in an open access repository here: https://docs.google.com/spreadsheets/d/1P2lFFMFBZakZYM0TWAZo9vdwNX-On8TaRj4H4sKJpgQ/edit#gid=0https://docs.google.com/spreadsheets/d/1P2lFFMFBZakZYM0TWAZo9vdwNX-On8TaRj4H4sKJpgQ/edit#gid=0.

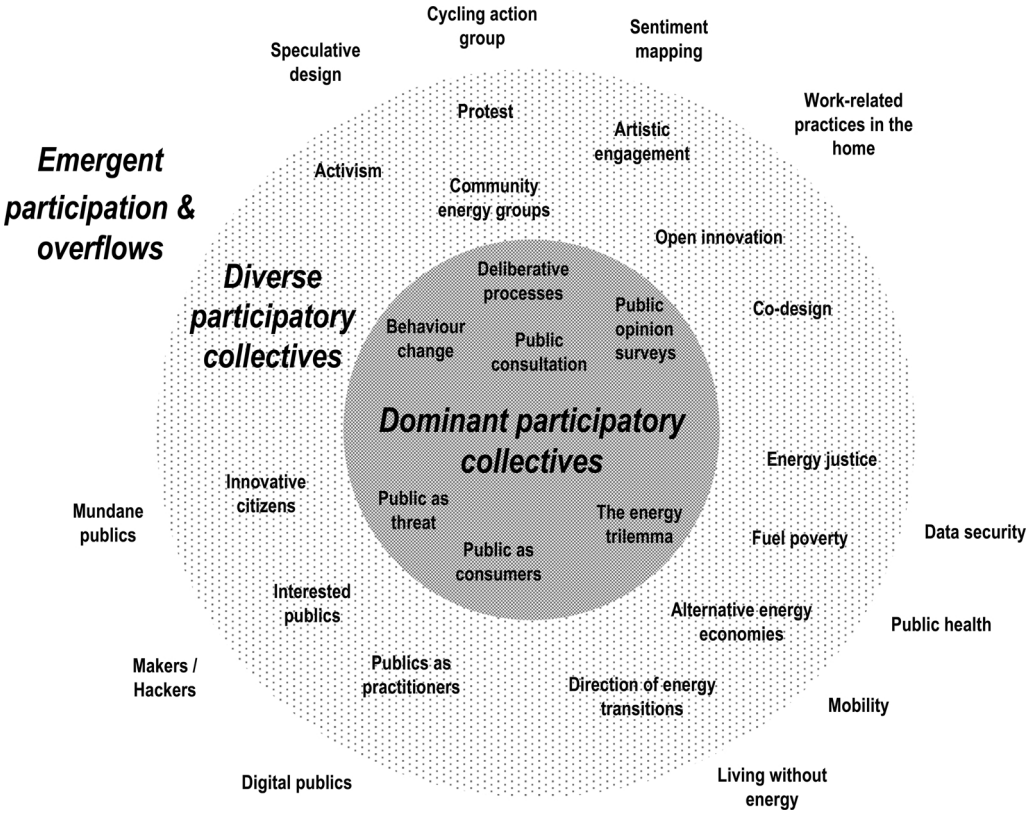

Fig. 2. An illustrative mapping of ecologies of participation in the UK energy system as constitution.

categories of (P) models of participation, (S) participating subjects, and (O) the energy-related objects produced in each case study. The coding structure was jointly created and tested on a sample of cases by the research team, which confirmed a high degree of inter-coder consistency and reliability. The coding of the whole corpus by the main analyst (HP) was then checked by the lead researcher (JC). Our analysis of these collectives guided by our interpretive conceptual framework offers a mapping of the diverse forms of participation, publics and energy issues reflected across the different cases, as well as a mapping of relations across the wider energy system-as-constitution, as presented in Section 4.1 below.

A subset of 30 cases (see Table 2) were selected for more detailed analysis to gain deeper insights into the construction and effects of different participatory collectives, how they interact, and relate to the wider energy system. This sample of 30 cases was not statistically representative of the whole corpus but rather was selected to capture diversity of key features in the wider corpus with respect to: the subjects, objects and models of participation; the inclusion of emerging collectives of participation; and geographical coverage across the four nations of the United Kingdom. Qualitative coding analysis of these 30 cases included a focus on the significant types of interrelations between collective participatory practices for which a number of categories were developed and then refined to produce six main types of interconnection between forms of energy participation, as presented in Section 4.2 below.

It should be noted that while broadening out beyond academic sources to include grey literature, the systematic mapping only captured participatory collectives that had been documented and publicised. Furthermore, the results of any mapping will be shaped by how it is framed. In the case of the current mapping, the focus on 'public' and 'civil society' engagement will not have actively included forms of participation centred on professional actors in formal institutions of the state, market and science. Issues of commercial confidentiality limited the inclusion of cases orchestrated by private companies, for example digital methods of sentiment mapping. Rather than ignore such framing effects our approach seeks to be openly reflexive of this, while deliberately opening up to diverse framings which both pushes out to include marginalised or emergent participatory collectives and makes the identification of dominant forms of participation in the mapping all the more significant.

In presenting one of the first empirical analyses of a system of participation in an energy (or indeed any other) setting, in the following subsections we first focus on the broader systemic patterns and dynamics of the ecology of participation in the UK energy system before presenting new insights into the significant types of interrelation between collectives of energy public engagement in socio-technical change.

4.1. Systemic diversities and inequalities of 'energy' participation

The rich and diverse empirical dataset produced by the systematic mapping poses challenges for how it is visualised. It has been analysed and presented in different ways, including through the use of infographics (see Pallett et al. [114] and Chilvers et al. [115]). Our emphasis in this paper is on illustrating the ecologies of participation and their interrelations with the wider system-as-constitution. To do this, in this sub-section we build on Irwin and Horst's [87] notion of 'centred' and 'decentred' public engagement as a way of mapping out the relations and relative positioning of participatory collectives in the wider energy system as constitution. In keeping with the three forms of relational space established in Fig. 1 – i.e. collective participatory practices, wider spaces of participation, and the energy system as constitution – Fig. 2 sets out an *illustrative* mapping space which differentiates between:

- *dominant participatory practices* that are well established, prevalent and more 'central' to the energy system as constitution;
- *diverse participatory practices*, which are established practices that

form part of wider spaces of participation and tend to be more marginal, 'decentred' or endangered in relation to what is commonly taken to mean the 'energy system';
- decentred participatory practices which, at a certain point in time, are either *emerging* in relation to the energy system or are deemed to *'overflow'* (exist outside of) it under particular frames of reference.

4.1.1. Dominant participatory collectives

Our mapping of collectives of UK energy participation shows some forms (models) of public engagement to be much more dominant and widespread than others in the energy system. Out of the 258 cases identified in the mapping the most predominant forms of participation were models for eliciting public views (91 cases) – including opinion surveys, consultations or deliberative processes – and forms of behaviour change (67 cases) including behaviour change programmes to shift energy demand through to more social practice based approaches to address energy consumption.

These dominant practices of energy participation were co-produced with dominant energy public identities (subjects), as shown through their co-occurrence in relevant cases. The most widespread framing of publics across the mapping dataset was as a mass to be consulted (i.e consultative publics), accounting for 119 cases in total – including communities affected by particular problems or new developments (33 cases) and collectives associated with a vision of an aggregate population to be represented, often through surveys and academic studies (30 cases). The construction of publics as consumer citizens was also strong (82 cases), including householders engaging with energy in the home (32 cases), users of technologies or infrastructures like smart meters and in-home displays (35 cases), and constructions of the public as consumers of energy or energy-related products (15 cases). These dominant constructions of energy publics as either an aggregate population or consumers creates broader systemic 'public closures' around who gets to speak about energy transitions, and how their visions will be interpreted and publicised.

Furthermore, these dominant participatory collectives were often narrowly framed in terms of the object of engagement, for example around the 'energy trilemma' in Government-led cases as well as some of the other cases from business and academia. They most often emphasised technological and behaviour change as the primary mechanisms of energy system change, often down-playing alternative models of progress or drivers of change. Dominant models, subjects and objects of participation, represented at the centre of Fig. 2, are continually reproduced meaning that systemic inequalities of participation exist within the wider energy system. From a systemic and constitutional perspective collectives of public engagement with energy are therefore not equal and are powerfully shaped by constitutional stabilities over what is collectively viewed as legitimate forms of participation and credible forms of evidence about energy publics (cf. [52]).

In this respect our mapping findings concur with constitutionally legitimate forms of energy participation documented in the literature, including the dominance of behaviour change and 'nudge' based approaches [88,89] as well as elicitation techniques, including deliberative public engagement and consultation [90]. This is related to entrenched institutional imaginaries of publics as possessing 'deficits' of knowledge and action (cf. [91]) when it comes to issues of energy and low carbon transitions, and a more general imaginary of the public in the UK as a threat to Government security, economic development and science-led progress [92]. Welsh and Wynne [92] argue that this is implicitly linked to concerns about dangers to the authority of science itself, which is an important source of Government legitimacy and 'evidence-based' policy-making.

Interpretive insights from other studies indicate the political economy of energy participation is another important driver of systemic inequalities revealed by the mapping exercise, where power and resourcing for orchestrating public engagement is mainly tied up in state, market and science institutions [93]. Yet the range of cases in our mapping results stress that constitutional stabilities and 'centred' forms of energy participation located in the middle of Fig. 2 do not only operate from the 'top-down' in a regime like fashion. Rather, they are continually produced and reproduced through the ongoing distributed performances of collective participatory practices throughout the system-as-constitution – including through everyday social practices, mundane forms of engagement with energy technologies, and 'publics performing publics' (cf. [32,94,95]).

4.1.2. Diverse participatory collectives

Set against this picture of constitutionally dominant forms of energy participation at the centre of Fig. 2, another key finding of our mapping results is the sheer diversity of established forms of energy participation that exist around this. While less common, participatory collectives illustrated in the second ring of Fig. 2 are more diverse, co-producing alternative subjects, models and objects of energy participation. These practices of public engagement have become established within wider spaces of participation, often beyond formal state, market and scientific institutions. Diverse models of participation revealed by the mapping include more bottom up and citizen-led forms of public demonstration through protest, activism, and art/performance-based engagement, through to bottom-up forms of citizen action in community energy projects and energy poverty action groups. Diverse forms of engagement were also evident in the formation of new relationships between public and private spheres, for example through open innovation and co-design in the development of smart energy technologies. These diverse models of participation were co-produced with more varied public identities evident in these cases, including more positive constructions of energy publics as active, creative, innovative, resourceful and knowledgeable. Framings of the objects, issues and visions associated with energy transitions are also more diverse within these cases, often opening up to alternative models of progress or drivers of change, such as ideas about de-growth or energy justice.

The fracking controversy provides a good example of these dynamics within the mapping dataset. Constitutionally legitimate participatory collectives – which government, business interests and (to an extent) academic research communities view as the most full and legitimate examples of public engagement around fracking in the UK – include opinion polls (e.g. [17]) and Government commissioned public dialogues (e.g. Case 5, Table 2). These forms of elicitation seek to understand public knowledge of fracking, public willingness to accept fracking technologies, and narrow concerns over the human health and safety implications of fracking (e.g. earthquakes, water and health impacts). Our mapping results reveal diverse collectives of public engagement in the fracking issue space beyond these institutionally sanctioned examples – including engagements by large NGOs, smaller social movements and campaign groups (Case 2 – Reclaim the Power), and local protesters (Case 25 – Back Balcombe). The crucial point here is that these more 'decentred' participatory collectives produced alternative views and wider concerns about fracking: about the broader *directions* of energy transitions; the need for alternatives to fossil fuels; as well as serious concerns over the *purposes* of fracking technologies and issues of *control*, *inclusion, equity* and *justice* (cf. [6,96]). Mapping across diverse forms of energy-related participation reveals these very real concerns, which are often denied or downplayed by incumbent interests but are central reasons for public resistance to disruptive energy technologies like fracking.

4.1.3. Emergent participation and overflows

The most 'decentred' collective participatory practices, which appear on the outside of Fig. 2, occurred less frequently at the time of study but are equally crucial to understanding the dynamics of participation in socio-technical change. Some of the collectives of energy participation identified in our mapping exercise were emergent in that they had recently become established or did not fit into established categories of public engagement with energy. In some cases, these new

Table 3
Significant types of interrelation within ecologies of ('energy') participation.

Type of interrelation	Description
Antecedence	Connections formed between collective participatory practices that existed in the past and present.
Replication	Similarly configured participatory collectives connect in wider technologized spaces which become more or less standardised across space, time and cultures.
Insulation	Dis-connections resulting from boundary work where participatory collectives become insulated from others.
Resistance	Situations where distinct participatory collectives resist, jostle and compete with each other in wider spaces of controversy or pathways of socio-technical change.
Assistance	The formation of solidarities and assistive relationships between otherwise distinct participatory collectives.
Transformation	Where a participatory collective transforms from one form of participation to another. For example, a fracking protest group transforming onto a community renewable energy initiative.

forms build on existing models of participation, for example Case 4 (the Bioenergy Distributed Dialogue) tried to develop new ways of carrying out public dialogues in a more distributed fashion. Other models of participation have been emerging for some time, such as the increasing focus in academic research on practices-that-use-energy, often in the home (Cases 10, 14, 15, 16 and 27, Table 2). New modes of participation are also evident from developments in technology, such as the emerging possibilities for conducting co-design and speculative design processes (e.g. Cases 12 and 20, Table 2). Digital methods of engagement were also identified as emerging in the mapping, for example with the development of sentiment mapping approaches which scan interactions on social media platforms and web forums for emotional responses to particular energy issues (e.g. Case 24, Table 2).

These cases emphasise that it is important to remain attentive to emergent participatory collectives across wider socio-technical systems because they introduce alternative models, and thus objects and subjects, of energy–related participation as well as providing foresight into models of participation that could become more central in future energy democracies. Such forms of participation are endangered in that they could just as easily be ephemeral practices that fade away or they could expand into wider spaces of standardisation over time and begin to exert greater productive effects on the energy system as constitution.

The sense of an ecology of participation that is continually emerging and in flux is further emphasised by collectives of public engagement revealed in the systematic mapping which go beyond, challenge or resist commonly held meanings of 'energy' and 'the energy system'. In this sense, some participatory collectives revealed in the mapping represent 'overflows' [1] in relation to the UK energy system-as-constitution which act upon it and continually animate and transform the assumed object(s) of socio-technical change. For example, Case 16 (domestic laundry practices) shows overflows between different social practices and parts of the energy system, for example illustrating how established working practices have implications for the temporality and frequency of energy-related practices.

In addition, many participatory collectives identified in the mapping were attending just as much to non-energy issues – like the protest group in Case 29 which raised issues about road networks and agricultural systems in relation to an energy-from-waste plant. Other collectives identified show the influence of 'non-energy participation' on the energy system itself (cf. [97]). In this sense, Case 19, the iconnect study of commuting behaviours, was ostensibly about improvements in infrastructures for walking and cycling which lead to environmental and public health benefits. But such benefits could also affect energy demand, for example from electric vehicles in the future, and so problematize meanings of 'energy' and whether such interventions are inside or outside of the energy system. This illustrates the value of an ecologies of participation perspective for understanding interconnections at the nexus of energy with other issues – such as food, waste, mobility, health, and social justice – as well as attending to 'overflows' of participation that can be deemed to lie outside of, but powerfully shape, energy systems.

4.2. Interrelations within ecologies of 'energy' participation

A central question that comes with the move beyond an imaginary of participation as isolated discrete events, is a more relational and systemic concern over how individual practices of participation interrelate with each other and connect up with wider spaces and systems of participation. Such insights are crucial to understanding the dynamics of energy participation and how systems of participation in socio-technical change transform over time. Taking this as a key analytical theme – through a grounded analysis of the mapping data informed by the framework presented in Fig. 1 – produced six significant types of interrelation between practices of energy-related participation, as summarised in Table 3.

4.2.1. Historical antecedence

The first kind of relationship between collective participatory practices concerns historical trajectories. In many cases identified in the systematic mapping it is difficult to establish exactly when a collective emerged because they are often strongly connected to earlier collectives through their form, purpose and key individuals involved. For example, this was the case with many activist and community groups. The emergence of Case 2 (Reclaim the Power) can be traced directly from the influential collective around the Camp for Climate Action which was active between 2006 and 2010, and through an interim working group called the Climate Justice Collective [98]. Similarly, Case 30 (Londoners on Bikes) emerged from earlier feminist and environmental activist collectives, as well as drawing on collectives which were specifically organised around cycling, including people involved in 'critical mass' cycles and the bike blogging community [86]. Connections between collectives over time were also evident in the policy sphere. Case 3 (DECC's Low Carbon Communities Challenge) involved community energy groups such as Transition Town Totnes and the Lammas eco village, all of whom had longer histories of energy action. Furthermore, the Low Carbon Communities Challenge concept emerged from an earlier public dialogue process orchestrated by DECC with support from Sciencewise, called the Big Energy Shift, which concluded that efforts towards behaviour change were best focussed at a community level (see also [90]). This relational connection of past collective agencies in configuring the politics of the present has also been emphasised in studies of energy decision-making and siting controversies (e.g. [99])

4.2.2. Replication: technologized spaces of participation

A second significant kind of relationship between participatory collectives in the mapping dataset is where similar participatory

collectives form into 'technologies of participation' which connect up in wider technologized spaces which are more or less standardised across space, time and cultures (cf. [100,46,30,47]). This type of connection is evident with dominant forms of energy participation (identified in Fig. 2, above). Public dialogue is a good example of a model of participation which has become replicated across space and time in the UK energy constitution, forming connections between UK Government sponsored public engagement around energy – including Case 3 (Low Carbon Communities Challenge), Case 4 (Bioenergy Distributed Dialogue), Case 5 (UK Government public engagement around shale gas and oil) and Case 6 (2050 public dialogue).

The mapping also showed how more decentred models of community energy are connected across the UK energy system, being adopted in many different contexts, places and institutional settings. For example, Case 8 (Northern Ireland Community Energy) and Case 18 (the Brighton Energy Co-op) both received advice from intermediary organisations like Co-operative Energy on how similar projects were run and they also looked at the business models used by other community energy groups [101]. This helps to explain certain patterns around community energy, such as the relatively limited range of organisational forms they often take [102]. Here we see collectives of community energy becoming connected in wider spaces of participation, within which particular models of participation in terms of community organising become more stabilised across space and time. This process applies to the way in which any collective participatory practice can replicate, expand and become more established within the wider UK energy system as constitution.

4.2.3. Insulation and boundary work

A third important relationship identified through in-depth case study analysis took the form of dis-connections resulting from boundary work [103] where participatory collectives become insulated from other collectives in wider ecologies of participation. A strong theme here is collectives which deliberately deny the existence, validity or relevance of other collectives operating in the same issue space. For example, the reporting of Case 5 (UK Government public engagement with shale gas and oil) did not make explicit connections to protests, media coverage and public opinion surveys in the fracking issue space which were going on in the same time-period. Where these collectives are mentioned in the documents concerning the process their relevance is down-played, and there was no attention paid to direct conjunctions between these collectives such as the existance of anti-fracking protests in the vicinity of one of the deliberative workshops which formed part of the dialogue [62]. Similarly, Case 11 (DECC public attitudes tracking) does not acknowledge protests and other forms of participation occurring around the energy issues and technologies it elicits public perceptions about.

In another example of this kind of disconnection, Case 13 (Renergy living labs) presents its methodology as completely different and novel, denying connections to other deliberative events attempting to engage communities around energy issues, even when they have occurred in the same areas. Other disconnections emerged from issues around publicising energy collectives. For example, the protests around Holsworthy energy-from-waste plant in Case 29 (community food waste energy production schemes) failed to connect up with other similar collectives or with national protests and organisation, due to its framing around concerns with agricultural waste and local issues such as road access.

4.2.4. Resistance

A fourth form of relation between participatory collectives revealed by the mapping dataset is where distinct participatory collectives resist, jostle and compete with each other in wider issue spaces [45], spaces of controversy [48] and pathways for socio-technical change [2,49]. For example, as detailed in Section 4.1, fracking was a very significant issue space which brought distinct participatory collectives into conflict during the period of our systematic mapping. As noted above, and reported in Case 22 (reporting of fracking in the UK press) which captures some of the multiple and overlapping participatory collectives operating in this space, these competing collectives produced alternative definitions and concerns of the fracking issue which became a symbolic battle field for broader contestations over the organisation and future direction of the UK energy system.

Other relations of resistance are evident where collectives actively try to reject and propose alternatives to more dominant energy collectives. For example, Case 14 (experiences of fuel poverty) explicitly rejected the picture of fuel poverty created by other collectives studied through statistical and survey methods and imagined in Government policy-making. Participatory collectives jostle and compete in innovation arenas, meaning that not all forms of participation and social innovation around renewable energy can 'scale up' (a key framing narrative of residual realist perspectives of participation). Renewable energy was an important example of this in the mapping dataset. Protests about the siting of renewable energy technologies, such as wind turbines (Case 7, Table 2) or energy-from-waste (Case 29, Table 2), have been largely dismissed or de-emphasised in explicit public enunciations by decision institutions, which have instead focused on aggregate levels of public support for renewables as expressed through public opinion surveys (Case 11, Table 2). While the community energy movement has significantly scaled-up and grown in influence over the past decade in the renewable energy space, there is evidence that these forms of participation are now also endangered by changes in subsidies and other Government policies [104]. More artistically led forms of public engagement with energy (Cases 9 and 20, Table 2) have also been consistently de-emphasised and under-supported, linked to their lack of credibility or dominance in policy discussions. These examples not only illustrate complex interrelations between participatory collectives, but also how they relate to and are configured by institutional and constitutional powers.

4.2.5. Assistance

A fifth significant relation between collectives of energy participation is the formation of solidarities and assistive relationships between otherwise distinct participatory collectives. For example, the mapping evidence shows that around particular issues several participatory collectives assist each other at key moments in promoting a similar agenda. For example, Case 2 (Reclaim the Power) has been identified by a number of analysts as part of a broader anti-fracking discourse coalition with other activist groups and collectives such as Case 25 (Back Balcombe), as well as individuals like the Green Party MP Caroline Lucas. Similarly, Case 7 (wind farm protests in Nant y Moch) formed part of a larger anti-wind turbine and anti-electricity pylon discourse coalition in rural Wales [64]. Case 21 (Demand Energy Equality) does much of its work in collaboration with other groups with similar aims related to the energy system, including 10:10, Greenpeace and the African Solar Cooperative, as well as collaborating with organisations with stronger social aims such as volunteering matters and local groups supporting people on low incomes or with addiction problems.

4.2.6. Collective transformation

Within the mapping dataset a sixth kind of connection between participatory collectives – which relates to the dynamic of overflows (as discussed in Section 4.1 above) – is where a participatory collective transforms from one form of participation to another. An excellent example of this within the mapping dataset is the case of Back Balcombe (Case 25) which morphed from an initial anti-fracking protest into a community energy group, which was then forced instead to enlist the help of a commercial energy company in response to cuts in feed-in tariffs. This not only illustrates how collective participatory practices transform and reconfigure through time but also how these dynamics of socio-technical change are shaped by (and shape) relational connections with the wider system as constitution, in this case formal

government interventions and market institutions.

5. Discussion and conclusions

Through developing and applying a new approach to understanding societal engagement with socio-technical change in this paper a picture emerges that is very different to mainstream residual realist accounts which adopt specific pre-given meanings of participation and the public and focus on discrete instances of public engagement in particular parts of socio-technical systems. The systemic and relational perspective developed in the above sections goes beyond received notions of engagement, revealing wider ecologies of multiple interrelating practices of energy-related participation that are constitutive of, shape, and are shaped by energy systems.

The analysis in Section 4.1 and Fig. 2 shows public engagements with energy transitions to be multiple, diverse, continually emerging, and overflowing accepted framings of the energy system in the UK – beyond what is routinely imagined, seen or heard by incumbent institutions. Our mapping has documented increasingly 'decentred' forms of societal engagement with energy coming into being as the UK energy system enters into a low carbon era characterised by more distributed forms of energy production and demand response (cf. [105]). Yet at the same time the analysis reveals significant systemic inequalities in UK energy participation, where certain forms of participation – particularly behaviour change and forms of public elicitation to gain social acceptance – are more prevalent, legitimate and 'central' than others. These findings demonstrate that not all collectives of public engagement are created equal. Practices of energy participation are shown to be powerfully shaped by the stabilities and driving forces of the energy system as constitution. This includes prevailing constitutional relations between citizens, science and the state [29] and hegemonic imaginaries of scientific and economic progress [11]. Constitutional stabilities are also evident in UK political culture where institutional assumptions about legitimate and credible forms of participation favour extractive methods of elicitation that can claim 'representativeness' of national publics (cf. [106]) or otherwise shift public behaviours into line with centrally managed priorities for low carbon transitions [89].

Analysis in Section 4.2 provides some of the first ever insights into the nature of interrelations between diverse practices of public engagement, thus deepening understandings of the dynamics of participation in socio-technical (energy) systems. While not exclusively so, the first three kinds of relation between participatory collectives – historical antecedence, replication in technologized spaces of participation, and insulation (Table 3) – can contribute to the formation and performance of stabilities within wider ecologies of participation and energy systems. The maintenance of socio-technical configurations over time, the growth and maintenance of particular forms of participation through processes of technologization and standardisation, and the protection of spaces of participation through insulation and boundary work can all contribute to these dynamics. Again, while not exclusively so, the further three types of interrelation between participatory collectives identified in our analysis – assistance, resistance, and transformation (Table 3) – can help explain processes of change and transformation within wider ecologies of participation. Whether this be through forming solidarities to build the collective powers of otherwise disparate participatory practices, through some participatory collectives winning out over others in the jostling between competing practices of participation, or through transformations occurring the level of individual participatory collectives. Ultimately, however, our analysis has revealed the importance of interrelations and mutual influence between collective practices of participation, which emphasises the continual interplay between *both* dynamics of closure and stability on the one hand and emergence and diversity on the other, in understanding socio-technical change in and around energy systems.

In this sense, these findings offer deeper insights into the dynamics of participation in socio-technical change compared to mainstream residual realist perspectives on energy participation. Through studying discrete isolated processes of participation that are assumed to exist outside of, and exert linear impacts on, socio-technical systems (e.g. information communication leading to shifts in energy consumption, or a deliberative process impacting on energy policy decisions), residual realist perspectives significantly downplay or simply miss complex socio-material relations revealed by the ecologies of participation approach developed in this paper. This includes the relational powers that continually act on the construction and performance of participatory collectives as revealed in our above analysis, including: constitutional stabilities, standardised techniques that prescribe how participatory collectives are formatted, forms of human agency, through to multiple interrelations with other participatory collectives. A relational ecologies approach eschews linear stories of socio-technical change, while also understanding participation as constitutive of rather than existing outside of socio-technical system change.

The 'systems of participation' perspective developed in this paper moves beyond the decisionism (cf. [107]) of residual realist perspectives, where participation and procedural justice are evaluated in terms of specific events or decision moments in government policy, consumption decisions of 'individual' consumers, and so on. As we have elaborated above, an ecologies of participation perspective provides insights into systemic inequalities of participation and inclusion in socio-technical change – about forms of participation that are dominant, endangered or non-present – which are not afforded by residual realist or even case-based relational approaches to participation (such as those reviewed in Section 2). A systemic relational ecologies approach thus offers new bases from which to evaluate or intervene in the *justices* of socio-technical systems, and opens up possibilities for future work to understand energy justice in more systemic and relational terms (cf. [5,108]).

A further important value of an ecological and systemic approach to energy participation is how it opens up to systemic diversities, emergence and overflows (as illustrated by Fig. 2). The approach captures diverse forms of energy participation otherwise excluded from pregiven framings of residual realist perspectives. It can attend to the ways in which publics, participation and social relations with energy are continually emerging and in flux. In addition, it does not take the problem or object of socio-technical change for granted or assume a unitary bounded system, but rather opens up to multiple, contested and ambiguous framings of 'the system' and objects of transition. As shown in Section 4.1, a relational ecologies approach thus remains alive to overflowing collectives which continually problematise and challenge the assumed objects, framings and trajectories of socio-technical change (e.g. 'the energy trilemma', 'low carbon' innovation, and so on).

Moves to ecologise participation present new challenges for developing methodological innovations that can map across and understand relations within and between the relational spaces set out in Fig. 1 [109]. The systematic mapping methodology drawn on in this paper represents one such mapping approach, using documentary evidence and secondary data. A number of other methods for mapping diversities of public and civil society involvement in socio-technical systems and controversies – such as issue mapping [110], controversy mapping [48], comparative case analyses [12] and mapping networks of practices [111] – are emerging and should be taken forward through further research and experimentation in the energy domain. Such mappings can provide more comprehensive forms of social intelligence about energy-related public values, knowledges, actions and visions that can help force public accountability of decision-making institutions, identify hitherto unidentified public concerns (often framed as 'barriers' to low carbon action), untapped catalysts for social change, help build solidarities between marginalised groups, and so on.

Yet, while mapping approaches – such as the one documented in this paper – can produce valuable systemic and plural forms of evidence, they are always partial. When it comes to interpretive analysis, further research using more situated, in-depth and ethnographic studies

is also needed to deepen empirical understandings of the relational spaces identified in Fig. 1 (above), and through comparative studies of other national energy systems and other analogous socio-technical systems beyond energy. When considering more interventionist uses of these emerging mapping approaches in energy policy and practice, it is important to note that these moves to ecologise participation do not replace, but rather should add to, complement and work with ongoing efforts to bring new collectives of energy participation into being in more reflexive and responsible ways (see [109]).

Finally, the new perspective on 'participation' in socio-technical change developed in this paper has implications for governing energy transitions. It highlights a crucial need to shift away from eliciting and 'fixing' public views in order to shape a vision of 'the transition' which is then centrally managed, towards a much more distributed and responsive mode of governing energy transitions. This effectively means turning participation around. The burden can no longer only be placed on publics to participate, but should equally be placed on institutions to account for the relevance of diverse publics and forms of participation across socio-technical systems (cf. [25,26]). This calls for new forms of institutional listening [cf. 112] to diversities of participation in energy transitions, as well as new ways of seeing public doings that are 'decentred' and excluded. The challenge is to develop systems of governance that can know, respond to and work with these diverse, emerging and ongoing forms of energy participation and not see them as something to be controlled or denied. Such responsiveness to ecologies of diverse and continually emergent public meanings, values and actions is crucial to building more socially sustainable, inclusive, responsible and just socio-technical (energy) transitions.

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References

[1] M. Callon, P. Lascoumes, Y. Barthe, Acting in an Uncertain World: An Essay on Technical Democracy, MIT Press, Cambridge, MA, 2009.
[2] M. Leach, I. Scoones, A. Stirling, Dynamic Sustainabilities: Technology, Environment, Social Justice, Earthscan, London, 2010.
[3] D. Loorbach, Transition management for sustainable development: a prescriptive, complexity-based governance framework, Gov. Int. J. Policy Adm. Inst. 23 (2010) 161–183.
[4] J. Stilgoe, R. Owen, P. Macnaghten, Developing a framework for responsible innovation, Res. Policy 42 (2013) 1568–1580.
[5] K. Bickerstaff, G. Walker, H. Bulkeley, Energy Justice in a Changing Climate: Social Equity and Low-carbon Energy, London, Zed Books Ltd, 2013.
[6] P. Macnaghten, J. Chilvers, The future of science governance: publics, policies, practices, Environ. Plann. C-Gov. Policy 32 (2014) 530–548.
[7] A. Corner, C. Groves, Breaking the climate change communication deadlock, Nat. Clim. Change 4 (2014) 743.
[8] Sciencewise Expert Resource Centre, The Government's Approach to Public Dialogue on Science and Technology, Department for Business Innovation and Skills, London, 2013.
[9] Behavioural Insights Team, Behaviour Change and Energy Use, Cabinet Office, London, 2011.
[10] G. Seyfang, A. Smith, Grassroots innovations for sustainable development: towards a new research and policy agenda, Environ. Polit. 16 (2007) 584–603.
[11] A. Stirling, Transforming power: social science and the politics of energy choices, Energy Res. Soc. Sci. 1 (2014) 83–95.
[12] J. Chilvers, N. Longhurst, Participation in transition(s): reconceiving public engagements in energy transitions as co-produced, emergent and diverse, J. Environ. Policy Plann. 18 (2016) 585–607.
[13] T.J. Foxon, Transition pathways for a UK low carbon electricity future, Energy Policy 52 (2013) 10–24.
[14] W. Abrahamse, L. Steg, C. Vlek, T. Rothengatter, A review of intervention studies aimed at household energy conservation, J. Environ. Psychol. 25 (2005) 273–291.
[15] P. Dolan, M. Hallsworth, D. Halpern, D. King, R. Metcalfe, I. Vlaev, Influencing behaviour: the mindspace way, J. Econ. Psychol. 33 (2012) 264–277.
[16] S. Stagl, Multicriteria evaluation and public participation: the case of UK energy policy, Land Use Policy 23 (2006) 53–62.
[17] DECC, DECC Public Attitudes Tracker -Wave 12, Department of Energy & Climate Change., London, 2015.
[18] C. Saunders, S. Price, One person's eu-topia, another's hell: climate camp as a heterotopia, Environ. Polit. 18 (2009) 117–122.
[19] B.K. Sovacool, What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda, Energy Res. Soc. Sci. 1 (2014) 1–29.
[20] G. Walker, N. Cass, Carbon reduction, 'the public' and renewable energy: engaging with socio-technical configurations, Area 39 (2007) 458–469.
[21] K. Asdal, N. Marres, Performing environmental change: the politics of social science methods, Environ. Plann. A 46 (2014) 2055–2064.
[22] S. Ureta, A very public mess: problematizing the participative turn in energy policy in Chile, Energy Res. Soc. Sci. 29 (2017) 127–134.
[23] A. Irwin, The politics of talk: coming to terms with the 'new' scientific governance, Soc. Stud. Sci. 36 (2006) 299–320.
[24] B. Wynne, Public engagement as a means of restoring public trust in science – hitting the notes, but missing the music? Commun. Genet. 9 (2006) 211–220.
[25] N. Marres, Material Participation: Technology, the Environment and Everyday Publics, Palgrave Macmillan, Basingstoke, 2012.
[26] J. Chilvers, M. Kearnes, Remaking Participation: Science, Environment and Emergent Publics, Routledge, Abingdon, 2016.
[27] M. Watson, How theories of practice can inform transition to a decarbonised transport system, J. Transp. Geogr. 24 (2012) 488–496.
[28] J. Parkinson, J. Mansbridge, Deliberative Systems: Deliberative Democracy at the Large Scale, Cambridge University Press, Cambridge, 2012.
[29] S. Jasanoff, Constitutional moments in governing science and technology, Sci. Eng. Ethics 17 (2011) 621–638.
[30] L. Soneryd, Technologies of participation and the making of technologized futures, in: J. Chilvers, M. Kearnes (Eds.), Remaking Participation: Science, Environment and Emergent Publics, Routledge, Abingdon, Oxon, 2016.
[31] A. Irwin, M. Michael, Science, Social Theory and Public Knowledge, Open University Press, Maidenhead, 2003.
[32] E. Shove, G. Walker, What is energy for? Social practice and energy demand, Theory Cult. Soc. 31 (2014) 41–58.
[33] M. Gross, The public proceduralization of contingency: bruno latour and the formation of collective experiments, Soc. Epistemol. 24 (2010) 63–74.
[34] A. Wilkie, M. Michael, M. Plummer-Fernandez, Speculative method and Twitter: bots, energy and three conceptual characters, Sociol. Rev. 63 (2015) 79–101.
[35] R. Bellamy, J. Chilvers, N.E. Vaughan, Deliberative Mapping of options for tackling climate change: citizens and specialists 'open up' appraisal of geoengineering, Public Underst. Sci. 25 (2016) 269–286.
[36] J. Grin, J. Rotmans, J. Schot, Transitions to Sustainable Development: New Directions in the Study of Long Term Transformative Change, Abingdon, Routledge, 2010.
[37] C.M. Hendriks, Policy design without democracy? Making democratic sense of transition management, Policy Sci. 42 (2009) 341–368.
[38] F.N. Laird, Against transitions? Uncovering conflicts in changing energy systems, Sci. Cult. 22 (2013) 149–156.
[39] E. Shove, M. Pantzar, M. Watson, The Dynamics of Social Practice: Everyday Life and How It Changes, Sage, London, 2012.
[40] A. Barry, Political situations: knowledge controversies in transnational governance, Crit. Policy Stud. 6 (2012) 324–336.
[41] S. Jasanoff, Science and Public Reason, London, Routledge, 2012.
[42] J. Bennett, Vibrant Matter: A Political Ecology of Things, Duke University Press, London, 2009.
[43] J. Chilvers, M. Kearnes, Participation in the making: rethinking public engagement in co-productionist terms, in: J. Chilvers, M. Kearnes (Eds.), Remaking Participation: Science, Environment and Emergent Publics, Routledge, Abingdon, 2016, pp. 31–63.
[44] B. Laurent, Democratic Experiments: Problematizing Nanotechnology and Democracy in Europe and the United States, MIT Press, Cambridge, M.A, 2017.
[45] N. Marres, The issues deserve more credit: pragmatist contributions to the study of public involvement in controversy, Soc. Stud. Sci. 37 (2007) 759–780.
[46] J. Chilvers, Environmental risk, uncertainty, and participation: mapping an emergent epistemic community, Environ. Plann. A 40 (2008) 2990–3008.
[47] J.-P. Voß, N. Amelung, Innovating public participation methods: technoscientization and reflexive engagement, Soc. Stud. Sci. 46 (2016) 749–772.
[48] B. Latour, Reassembling the Social: An Introduction to Actor-network-theory, Oxford University Press, Oxford, 2005.
[49] U. Jørgensen, Mapping and navigating transitions—the multi-level perspective compared with arenas of development, Res. Policy 41 (2012) 996–1010.
[50] U. Felt, B. Wynne, Taking European Knowledge Society Seriously, European Commission, 2007.
[51] S. Jasanoff, Reframing Rights: Bioconstitutionalism in the Genetic Age, MIT Press, Cambridge, M.A, 2011.
[52] S. Jasanoff, Designs on Nature: Science and Democracy in Europe and the United States, Princeton University Press, Princeton, NJ, 2005.
[53] M. Begon, C.R. Townsend, J.L. Harper, Ecology: from Individuals to Ecosystems, Blackwell, Oxford, 2006.
[54] F.W. Geels, Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study, Res. Policy 31 (2002) 1257–1274.
[55] C. Heath, D. vom Lehn, Configuring 'interactivity': enhancing engagement in science centres and museums, Soc. Stud. Sci. 38 (2008) 63–91.
[56] S.L. Star, J.R. Griesemer, Institutional ecology, translations, and boundary objects: amateurs and professionals in Berkeley's Museum of Vertebrate Zoology 1907-39, Soc. Stud. Sci. 19 (1989) 387–420.

[57] I. Stengers, Introductory notes on an ecology of practices, Cult. Stud. Rev. 11 (2013) 183–196.
[58] K. Parkhill, C. Demski, C. Butler, A. Spence, N. Pidgeon, Transforming the UK Energy System: Public Values, Attitudes and Acceptability – Synthesis Report, UKERC, London, 2013.
[59] Reclaim the Power, Reclaim the Power, (2017) (Available at:), https://reclaimthepower.org.uk/.
[60] DECC, Low Carbon Communities Challenge: Evaluation Report, HM Government, London, 2012.
[61] BBSRC, Bioenergy Dialogue: Final Report, BBSRC, Swindon, 2013.
[62] TNS BMRB, Public Engagement with Shale Gas and Oil, TNS BMRB, London, 2014.
[63] N. Comber, S. Sheikh, Evaluation and Learning from the 2050 Public Engagement Programme, Office for Public Management, London, 2011.
[64] K. Mason, P. Milbourne, Constructing a 'landscape justice' for windfarm development: the case of Nant Y Moch, Wales, Geoforum 53 (2014) 104–115.
[65] NICE, Northern Ireland Community Energy, (2017) (Available at:), http://www.nicommunityenergy.org/.
[66] J. Allen, S.P. Jones, Tilting at Windmills in a changing climate: a performative walking practice and dance-documentary film as an embodied mode of engagement and persuasion, Res. Drama Educ.: J. Appl. Theatre Perform. 17 (2012) 209–227.
[67] H. Bulkeley, G. Powells, S. Bell, Smart grids and the constitution of solar electricity conduct, Environ. Plann. A 48 (2016) 7–23.
[68] Febubabble, Energy and Co-designing Communities, (2017) (Available at:), www.ecdc.ac.uk.
[69] J. Dvarioniene, I. Gurauskiene, G. Gecevicius, D.R. Trummer, C. Selada, I. Marques, C. Cosmi, Stakeholders involvement for energy conscious communities: the Energy Labs experience in 10 European communities, Renew. Energy 75 (2015) 512–518.
[70] L. Middlemiss, R. Gillard, Fuel poverty from the bottom-up: characterising household energy vulnerability through the lived experience of the fuel poor, Energy Res. Soc. Sci. 6 (2015) 146–154.
[71] K. Henwood, N. Pidgeon, C. Groves, F. Shirani, C. Butler, K. Parkhill, Energy Biographies Research Report, CER, Cardiff, 2015.
[72] S. Higginson, M. Thomson, T. Bhamra, For the times they are a-changin: the impact of shifting energy-use practices in time and space, Local Environ. 19 (2014) 520–538.
[73] C. Wilson, G. Chryssochoidis, H. Pettifor, Understanding Homeowners' Renovation Decisions: Findings of the VERD Project UKERC Working Paper Series, (2013).
[74] S. Hielscher, Brighton energy co-op: an innovation history, A Report for the CISE Project, UEA, Norwich, 2012.
[75] C. Brand, A. Goodman, D. Ogilvie, F. Bull, A. Cooper, A. Day, N. Mutrie, J. Powell, J. Preston, H. Rutter, Evaluating the impacts of new walking and cycling infrastructure on carbon dioxide emissions from motorized travel: a controlled longitudinal study, Appl. Energy 128 (2014) 284–295.
[76] F. Bowden, D. Lockton, R. Gheerawo, C. Brass, Drawing Energy: Exploring Perceptions of the Invisible, Royal College of Art, London, 2015.
[77] Demand Energy Equality, Demand Energy Equality, (2017) (Available at:), www.demandenergyequality.org.
[78] R. Jaspal, B. Nerlich, Fracking in the UK press: threat dynamics in an unfolding debate, Public Underst. Sci. 23 (2014) 348–363.
[79] J. Liu, R. Yao, R. McCloy, An investigation of thermal comfort adaptation behaviour in office buildings in the UK, Indoor Built Environ. 23 (2014) 675–691.
[80] K. Beckman, How to use social media: a quick guide for utility companies, Energy Post (2015).
[81] 10:10, Back Balcombe, (2017) (Available at:), https://1010uk.org/back-balcombe.
[82] P. Devine-Wright, S. Batel, Explaining public preferences for high voltage pylon designs: an empirical study of perceived fit in a rural landscape, Land Use Policy 31 (2013) 640–649.
[83] C. Liddell, Smart Meters: Smart People, University of Ulster, Ulster, 2013.
[84] M. Phillips, J. Dickie, Narratives of transition/non-transition towards low carbon futures within English rural communities, J. Rural Stud. 34 (2014) 79–95.
[85] C. Alexander, J.O. Reno, From biopower to energopolitics in England's modern waste technology, Anthropol. Q. 87 (2014) 335–358.
[86] R. Aldred, Who are Londoners on Bikes and what do they want? Negotiating identity and issue definition in a 'pop-up' cycle campaign, J. Transp. Geogr. 30 (2013) 194–201.
[87] A. Irwin, M. Horst, Engaging in a decentred world: overflows, ambiguities, and the governance of climate change, in: J. Chilvers, M. Kearnes (Eds.), Remaking Participation: Science, Environment and Emergent Publics, Routledge, Abingdon, Oxon, 2016, pp. 64–80.
[88] S. Owens, L. Driffill, How to change attitudes and behaviours in the context of energy, Energy Policy 36 (2008) 4412–4418.
[89] R. Jones, J. Pykett, M. Whitehead, Changing Behaviours: On the Rise of the Psychological State, Edward Elgar, Cheltenham, 2013.
[90] H. Pallett, J. Chilvers, A decade of learning about publics, participation, and climate change: institutionalising reflexivity? Environ. Plann. A 45 (2013) 1162–1183.
[91] B. Wynne, Knowledges in context, Sci. Technol. Hum. Values 16 (1991) 111–121.
[92] I. Welsh, B. Wynne, Science, scientism and imaginaries of publics in the UK: passive objects, incipient threats, Sci. Cult. 22 (2013) 540–566.
[93] J. Chilvers, Expertise, professionalization and reflexivity in mediating public participation: perspectives from STS and British Science and Democracy, in: L. Bherer, M. Gauthier, L. Simard (Eds.), The Professionalization of Public Participation, Routledge, Abingdon, 2017, pp. 115–138.
[94] M. Michael, Publics performing publics: of PiGs, PiPs and politics, Public Underst. Sci. 18 (2009) 617–631.
[95] M. Michael, Engaging the mundane: complexity and speculation in everyday technoscience, in: J. Chilvers, M. Kearnes (Eds.), Remaking Participation: Science, Environment and Emergent Publics, Routledge, Abingdon, Oxon, 2016, pp. 81–98.
[96] L. Williams, P. Macnaghten, R. Davies, S. Curtis, Framing 'fracking': exploring public perceptions of hydraulic fracturing in the United Kingdom, Public Underst. Sci. 26 (2017) 89–104.
[97] E. Cox, S. Royston, J. Selby, The Impacts of Non-energy Policies on the Energy System: A Scoping Paper, UK Energy Research Centre, London, 2016.
[98] N. Bergman, Climate Camp and public discourse of climate change in the UK, Carbon Manage. 5 (2014) 339–348.
[99] K. Bickerstaff, Because we've got history here: nuclear waste, cooperative siting, and the relational geography of a complex issue, Environ. Plann. A 44 (2012) 2611–2628.
[100] J. Lezaun, L. Soneryd, Consulting citizens: technologies of elicitation and the mobility of publics, Public Underst. Sci. 16 (2007) 279–297.
[101] T. Hargreaves, S. Hielscher, G. Seyfang, A. Smith, Grassroots innovations in community energy: the role of intermediaries in niche development, Global Environ. Change-Hum. Policy Dimens. 23 (2013) 868–880.
[102] G. Seyfang, J.J. Park, A. Smith, A thousand flowers blooming? An examination of community energy in the UK, Energy Policy 61 (2013) 977–989.
[103] T.E. Gieryn, Boundaries of science, in: S. Jasanoff, G. Markle, J. Petersen, T. Pinch (Eds.), The Handbook of Science and Technology Studies, first ed., Sage, Thousand Oaks, California, 1995, pp. 393–443.
[104] A. Smith, T. Hargreaves, S. Hielscher, M. Martiskainen, G. Seyfang, Making the most of community energies: three perspectives on grassroots innovation, Environ. Plann. A 48 (2016) 407–432.
[105] T. Mitchell, Carbon Democracy: Political Power in the Age of Oil, Verso, London, 2011.
[106] T. Osborne, N. Rose, Do the social sciences create phenomena?: the example of public opinion research, Br. J. Sociol. 50 (1999) 367–396.
[107] B. Wynne, Seasick on the third wave? Subverting the hegemony of propositionalism: response to Collins & Evans (2002), Soc. Stud. Sci. 33 (2003) 401–417.
[108] A. Forman, Energy justice at the end of the wire: enacting community energy and equity in Wales, Energy Policy 107 (2017) 649–657.
[109] J. Chilvers, M. Kearnes, Remaking participation: towards reflexive engagement, in: J. Chilvers, M. Kearnes (Eds.), Remaking Participation: Science, Environment and Emerging Publics, Routledge, Abingdon, 2016, pp. 261–288.
[110] N. Marres, Why map issues? On controversy analysis as a digital method, Sci. Technol. Hum. Values 40 (2015) 655–686.
[111] S. Higginson, E. McKenna, T. Hargreaves, J. Chilvers, M. Thomson, Diagramming social practice theory: an interdisciplinary experiment exploring practices as networks, Indoor Built Environ. 24 (2015) 950–969.
[112] A. Dobson, Listening for Democracy: Recognition, Representation, Reconciliation, Oxford University Press, Oxford, 2014.
[113] P.J. Gehrke, Ecological validity and the study of publics: the case for organic public engagement methods, Public Underst. Sci. 23 (2014) 77–91.
[114] H. Pallett, J. Chilvers, T. Hargreaves, Mapping Energy Participation: A Systematic Review of Diverse Practices of Participation in UK Energy Transitions , 2010–2015, UK Energy Research Centre, London, 2017.
[115] J. Chilvers, H. Pallett, T. Hargreaves, Public Engagement with Energy: Broadening Evidence, Policy and Practice, UK Energy Research Centre, London, 2017.